Gent_McWilliams Parameterization in a Hybrid Coordinate Ocean Model

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Ocean circulation models based on Cartesian coordinates with pressure as the vertical coordinate remain the most popular option for ocean climate models. While models based isopycnal and hybrid coordinates offer the potential of much greater accuracy, they generally do not have the detailed parameterizations of near surface processes contained in the "state of the art" ocean climate models. Isopycnal and hybrid ocean models are being improved,   but at the same time more conventional p-coordinate models are also being refined through better parameterization. This makes the gap in climate community acceptance between P-coordinate and hybrid isopycnal coordinate models harder to close.

State of the art p-coordinate ocean climate models include the Gent-McWilliams parameterization. This parameterization insures that sub-grid scale lateral mixing in an ocean model does not mix across density surfaces. It also parameterizes the effect of meso-scale eddies by for smoothing out of isopycnal thickness gradients. It is generally felt that these processes are already included in models in which the coordinate surfaces are aligned with density surfaces. However, in the case of hybrid models, in which an isopycnal coordinate system is used to represent the main thermocline, and a p-coordinate system is used to represent the mixed layer and transition region, this is not true. Density surfaces and coordinate surfaces will not coincide everywhere and something like the Gent-McWilliams parameterization is required.

The effort at Princeton is developing a model which combines existing elements of the Hallberg HIM isopycnal model and the "neutral physics" package of the MOM ocean circulation model. The combined hybrid model is a representation of the World Ocean utilizing 30 processors. The upper 200 meters of the ocean is represented in pressure coordinates with a resolution of 10 decibars, while the main thermocline and the deep ocean are represented by isopycnal coordinates. The KPP parameterization is used to describe vertical mixing, while the "neutral physics" package of MOM is used to include the Gent_McWilliams parameterization of horizontal mixing along density surfaces. Although the MOM and HIM models are supposed to be modular, combining subroutines from different models and porting them to a massively parallel machines is quite complex and the combined model is still being developed. Preliminary results are shown in which the Gent_McWilliams parameterization is only implemented in the upper ocean p-coordinate region of the hybrid version of HIM. An important goal is to largely eliminate the spurious leakage of water mass properties across density surfaces at the base of the mixed layer that has been noted in previous hybrid ocean circulation models.